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OPERATING SYSTEMS

CSE2005

NACHOS

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ABSTRACT

- **Not Another Completely Heuristic Operating System**, or **Nachos**, is instructional software for teaching undergraduate, and potentially graduate level operating systems courses. It was developed at the University of California, Berkeley, designed by Thomas Anderson, and is used by numerous schools around the world.
- Originally written in C++ for MIPS, Nachos runs as a user-process on a host operating system. A MIPS simulator executes the code for any user programs running on top of the Nachos operating system. Ports of the Nachos code exist for a variety of architectures.
- In addition to the Nachos code, a number of assignments are provided with the Nachos system. The goal of Nachos is to introduce students to concepts in operating system design and implementation by requiring them to implement significant pieces of functionality within the Nachos system.

THE ARCHITECTURE OF NACHOS

SYSTEM START-UP FLOWCHART

SOFTWARES AND TOOLS USED FOR INSTALLATION OF NACHOS AND CROSS COMPILER

- VIRTUAL MACHINE & IMAGE

  •VIRTUAL MACHINE RUNS ON YOUR CURRENT OS. EG. VIRTUAL BOX, VMWARE…

- UBUNTU DESKTOP

  HTTP://WWW.UBUNTU.COM/DOWNLOAD/DESKTOP/

  - DOWNLOAD THE IMAGE (.ISO FILE).(**16.04 VERSION-32 BIT**)
  - LOAD THE IMAGE INTO YOUR VIRTUAL MACHINE.
  - OR YOU CAN SET UP YOUR OWN NEW VIRTUAL MACHINE

- NACHOS-4.0 VERSION WAS DOWNLOADED AND EXTRACTED MANUALLY,
- MIPS-DECSTATION-ULTRIX CROSS COMPILER WAS DOWNLOADED AND EXTRACTED MANUALLY.
- INSTALL G++, CSH AND SU

  SUDO APT-GET INSTALL G++

  SUDO APT-GET INSTALL CSH

  SUDO -SU

- EMACS 24 EDITOR WAS INSTALLED AND USED.
- MIPS-DECSTATION COMPILER WAS MOVED FROM HOME TO USR/LOCAL AND THAT PATH WAS USED IN THE MAKEFILE.

INSTALLING UBUNTU

INSTALLING VIRTUAL BOX-

Open the VirtualBox website. Go to https://www.virtualbox.org/ in your computer's Internet browser. This is the website from which you'll download the VirtualBox setup file.
Navigate to the downloads folder on your computer and double-click the VirtualBoxinstaller.
1.The first screen is a welcome screen. Click **Next** to move on.
2.You will be asked which components you wish to install. I recommend leaving the default options selected.
3.Click **Next** to go to the Custom Setup screen.
4.Choose which folder you want VirtualBox to appear in using the Windows menu structure.
5.Click **Next**.
6.At this point, you can choose whether to create a desktop shortcut or not.
7.Click **Next** and you are taken to the Network Warning screen.
8.You are now ready to install Oracle VirtualBox.
Click **Install** to start the installation.
9.During the installation, you may be asked for permission to install the application and your antivirus and firewall software may request permission to install VirtualBox. Be sure to allow those permissions.

CREATING A VIRTUAL MACHINE

Oracle VirtualBox has a lot of options and it is worth exploring all of these and reading the help guide but for the sake of this tutorial click the **New** icon on the toolbar.

The first thing you need to do is define the type of virtual machine you wish to create.

1. Enter a descriptive name into the Name box.
2. Select **Linux** as the Type.
3. Choose **Ubuntu** as the Version.
4. Click **Next** to continue.

Allocate Memory to the Virtual Machine

The next screen asks you to set how much memory you wish to give over to the virtual machine.

You should not go below the minimum specified and you should also make sure you leave enough memory for the host operating system (Windows) to keep running.

Create a Virtual Hard Drive

The next three steps are all about allocating disk space to the virtual machine.

If you want to run Ubuntu as a live image then you do not need to create a hard driveat all but for installing Ubuntu you will need to.

1.Select **Create a virtual hard drive now**.
2.Click **Create**.
3.You will be asked to select the type of hard drive to create. The default VDI file type is the one native to VirtualBox, so select **VDI**.
4.Click **Next**.
When deciding on the way the hard drive is created you can choose to opt for a fixed size hard drive or a dynamically sized hard drive.
5.Select your desired hard drive type.
6.Click **Next**.
7.After specifying the hard drive type and the way the disk is allocated you are asked to specify how much disk space you are going to give over to the Ubuntu Virtual Machine. Do not go below the minimum set and create enough disk space to make it worthwhile. We recommend at least 15 gigabytes.
8.Choose where you wish to save the virtual machine.
9.Specify the disk size.
10.Click **Create.**

Start the Virtual Machine
The Virtual Machine has now been created and you can start it by pressing the **Start** button on the toolbar.
The first boot requires you to select a startup disk.
1.Click the **folder** icon.
2.Navigate to the downloads folder and select **Ubuntu ISO.**
3.Click **Start.**

Ubuntu will now boot into a live version of the operating system and a welcome message appears.
You will be asked to select your language and you will be able to choose whether to Try Ubuntu or Install Ubuntu.
If you decide to try Ubuntu first you can always run the installer by double-clicking on the **Install** icon on the Ubuntu desktop.

Choose Your Installation Language

Now we are into the nitty-gritty of installing Ubuntu.
The first step is to choose the installation language.
1.Choose a language.
2.Click **Continue**.
3.There are two checkboxes at the bottom of the screen. Choose whether to **install updates as you go**.
4.Then choose whether to **install 3rd party software**.
5.Click **Continue**.

Partitioning a Virtual Hard Drive

The Installation Type screen asks you how you wish to partition the hard drive.
1.Select **Erase disk and install Ubuntu**.
2.Click **Install Now**.
3.The installation begins and the files are copied to the virtual hard drive.

Now choose a location.
Then create a user and password for it.

Completing the Installation

The final stage is to wait for the files to finish copying and the installation to complete.
When the process is complete you will be asked to reboot. This, of course, refers to the virtual machine and not your host Windows machine

INSTALLATION OF NACHOS

STEP 1: mv decstation-Ultrix /usr/local

STEP 2: nachos-4.0/code/make

```
Desktop    Downloads         Music   Pictures  Templates
Documents  examples.desktop  nachos  Public    Videos
root@apoorv:/home/apoorv# mv nachos ../usr/local
mv: cannot move 'nachos' to '../usr/local': No such file or directory
root@apoorv:/home/apoorv# mv nachos ./usr/local
mv: cannot move 'nachos' to './usr/local': No such file or directory
root@apoorv:/home/apoorv# mv nachos ./usr/local/
mv: cannot move 'nachos' to './usr/local/': No such file or directory
root@apoorv:/home/apoorv# sudo mv nachos /usr/local
root@apoorv:/home/apoorv# ls
Desktop  Documents  Downloads  examples.desktop  Music  nachos-4.0  nachos-4.0.tar.gz  Pictures  Public  Templates  Videos
root@apoorv:/home/apoorv# cd nachos-4.0/code
root@apoorv:/home/apoorv/nachos-4.0/code# make
cd threads; make depend
make[1]: Entering directory '/home/apoorv/nachos-4.0/code/threads'
g++ -Wno-deprecated -I../lib -I../threads -I../machine -DTHREADS -Dx86 -DLINUX -DBSD -M ../lib/bitmap.cc ../lib/debug.cc ../lib/hash.cc ../lib/libtest.cc ../lib/list.cc ../lib/sysdep.cc ../machine/interru
pt.cc ../machine/stats.cc ../machine/timer.cc ../threads/alarm.cc ../threads/kernel.cc ../threads/main.cc ../threads/scheduler.cc ../threads/synch.cc ../threads/synchlist.cc ../threads/thread.cc ../machin
e/elevatortest.cc ../machine/elevator.cc > makedep
echo '/^# DO NOT DELETE THIS LINE/+2,$d' >eddep
echo '$r makedep' >>eddep
echo 'w' >>eddep
echo 'q' >>eddep
ed - Makefile < eddep
rm eddep makedep
echo '# DEPENDENCIES MUST END AT END OF FILE' >> Makefile
echo '# IF YOU PUT STUFF HERE IT WILL GO AWAY' >> Makefile
echo '# see make depend above' >> Makefile
make[1]: Leaving directory '/home/apoorv/nachos-4.0/code/threads'
cd threads; make nachos
make[1]: Entering directory '/home/apoorv/nachos-4.0/code/threads'
g++ -Wno-deprecated -g -Wall -I../lib -I../threads -I../machine -DTHREADS -Dx86 -DLINUX -DBSD -DCHANGED -c ../lib/bitmap.cc
g++ -Wno-deprecated -g -Wall -I../lib -I../threads -I../machine -DTHREADS -Dx86 -DLINUX -DBSD -DCHANGED -c ../lib/debug.cc
g++ -Wno-deprecated -g -Wall -I../lib -I../threads -I../machine -DTHREADS -Dx86 -DLINUX -DBSD -DCHANGED -c ../lib/libtest.cc
../lib/libtest.cc:59:46: warning: deprecated conversion from string constant to ‘char*’ [-Wwrite-strings]
   "7", "8", "9", "10", "11", "12", "13", "14"};
                                              ^
../lib/libtest.cc:59:46: warning: deprecated conversion from string constant to ‘char*’ [-Wwrite-strings]
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../lib/libtest.cc:59:46: warning: deprecated conversion from string constant to ‘char*’ [-Wwrite-strings]
g++ -Wno-deprecated -g -Wall -I../lib -I../threads -I../machine -DTHREADS -Dx86 -DLINUX -DBSD -DCHANGED -c ../lib/sysdep.cc
g++ -Wno-deprecated -g -Wall -I../lib -I../threads -I../machine -DTHREADS -Dx86 -DLINUX -DBSD -DCHANGED -c ../machine/interrupt.cc
../machine/interrupt.cc:29:45: warning: deprecated conversion from string constant to ‘char*’ [-Wwrite-strings]
 static char *intLevelNames[] = { "off", "on"};
```

Screenshot

```
                                                                    ^
../machine/interrupt.cc:29:45: warning: deprecated conversion from string constant to 'char*' [-Wwrite-strings]
../machine/interrupt.cc:32:18: warning: deprecated conversion from string constant to 'char*' [-Wwrite-strings]
    "network recv"};
                  ^
../machine/interrupt.cc:32:18: warning: deprecated conversion from string constant to 'char*' [-Wwrite-strings]
../machine/interrupt.cc:32:18: warning: deprecated conversion from string constant to 'char*' [-Wwrite-strings]
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../machine/interrupt.cc:32:18: warning: deprecated conversion from string constant to 'char*' [-Wwrite-strings]
../machine/interrupt.cc:32:18: warning: deprecated conversion from string constant to 'char*' [-Wwrite-strings]
g++ -Wno-deprecated -g -Wall -I../lib -I../threads -I../machine -DTHREADS -Dx86 -DLINUX -DBSD -DCHANGED -c ../machine/stats.cc
g++ -Wno-deprecated -g -Wall -I../lib -I../threads -I../machine -DTHREADS -Dx86 -DLINUX -DBSD -DCHANGED -c ../machine/timer.cc
g++ -Wno-deprecated -g -Wall -I../lib -I../threads -I../machine -DTHREADS -Dx86 -DLINUX -DBSD -DCHANGED -c ../threads/alarm.cc
g++ -Wno-deprecated -g -Wall -I../lib -I../threads -I../machine -DTHREADS -Dx86 -DLINUX -DBSD -DCHANGED -c ../threads/kernel.cc
../threads/kernel.cc: In member function 'void ThreadedKernel::Initialize()':
../threads/kernel.cc:59:38: warning: deprecated conversion from string constant to 'char*' [-Wwrite-strings]
    currentThread = new Thread("main");
                                     ^
../threads/kernel.cc: In member function 'void ThreadedKernel::SelfTest()':
../threads/kernel.cc:114:39: warning: deprecated conversion from string constant to 'char*' [-Wwrite-strings]
    semaphore = new Semaphore("test", 0);
                                      ^
In file included from ../threads/synchlist.h:50:0,
                 from ../threads/kernel.cc:14:
../threads/synchlist.cc: In instantiation of 'SynchList<T>::SynchList() [with T = int]':
../threads/kernel.cc:120:20:   required from here
../threads/synchlist.cc:26:10: warning: deprecated conversion from string constant to 'char*' [-Wwrite-strings]
    lock = new Lock("list lock");
           ^
../threads/synchlist.cc:27:15: warning: deprecated conversion from string constant to 'char*' [-Wwrite-strings]
    listEmpty = new Condition("list empty cond");
                ^
../threads/synchlist.cc: In instantiation of 'void SynchList<T>::SelfTest(T) [with T = int]':
../threads/kernel.cc:121:25:   required from here
../threads/synchlist.cc:127:39: warning: deprecated conversion from string constant to 'char*' [-Wwrite-strings]
    Thread *helper = new Thread("ping");
                                        ^
g++ -Wno-deprecated -g -Wall -I../lib -I../threads -I../machine -DTHREADS -Dx86 -DLINUX -DBSD -DCHANGED -c ../threads/main.cc
In file included from ../threads/main.cc:18:0:
../lib/copyright.h:23:26: warning: deprecated conversion from string constant to 'char*' [-Wwrite-strings]
 static char *copyright = "Copyright (c) 1992-1993 The Regents of the University of California.  All rights reserved.";
                          ^
../threads/main.cc: In function 'int main(int, char**)':
../threads/main.cc:59:22: warning: deprecated conversion from string constant to 'char*' [-Wwrite-strings]
    char *debugArg = "";
                     ^
g++ -Wno-deprecated -g -Wall -I../lib -I../threads -I../machine -DTHREADS -Dx86 -DLINUX -DBSD -DCHANGED -c ../threads/scheduler.cc
g++ -Wno-deprecated -g -Wall -I../lib -I../threads -I../machine -DTHREADS -Dx86 -DLINUX -DBSD -DCHANGED -c ../threads/synch.cc
../threads/synch.cc: In member function 'void Semaphore::SelfTest()':
../threads/synch.cc:143:39: warning: deprecated conversion from string constant to 'char*' [-Wwrite-strings]
    Thread *helper = new Thread("ping");
                                        ^
../threads/synch.cc:146:35: warning: deprecated conversion from string constant to 'char*' [-Wwrite-strings]
```

Screenshot

```
make[1]: Entering directory '/home/apoorv/nachos-4.0/code/test'
/usr/local/nachos/decstation-ultrix/bin/gcc -G 0 -c -I../userprog -I../threads -I../lib -I../userprog -I../threads -I../lib  -c -o halt.o halt.c
/lib/cpp -I../userprog -I../threads -I../lib start.s > strt.s
/usr/local/nachos/decstation-ultrix/bin/as -mips2 -o start.o strt.s
rm strt.s
/usr/local/nachos/decstation-ultrix/bin/ld -T script -N start.o halt.o -o halt.coff
../bin/coff2noff halt.coff halt
numsections 3
Loading 3 sections:
        ".text", filepos 0xd0, mempos 0x0, size 0x110
        ".data", filepos 0x1e0, mempos 0x110, size 0x0
        ".bss", filepos 0x0, mempos 0x110, size 0x0
/usr/local/nachos/decstation-ultrix/bin/gcc -G 0 -c -I../userprog -I../threads -I../lib -I../userprog -I../threads -I../lib  -c -o shell.o shell.c
/usr/local/nachos/decstation-ultrix/bin/ld -T script -N start.o shell.o -o shell.coff
../bin/coff2noff shell.coff shell
numsections 3
Loading 3 sections:
        ".text", filepos 0xd0, mempos 0x0, size 0x210
        ".data", filepos 0x2e0, mempos 0x210, size 0x0
        ".bss", filepos 0x0, mempos 0x210, size 0x0
/usr/local/nachos/decstation-ultrix/bin/gcc -G 0 -c -I../userprog -I../threads -I../lib -I../userprog -I../threads -I../lib  -c -o matmult.o matmult.c
/usr/local/nachos/decstation-ultrix/bin/ld -T script -N start.o matmult.o -o matmult.coff
../bin/coff2noff matmult.coff matmult
numsections 3
Loading 3 sections:
        ".text", filepos 0xd0, mempos 0x0, size 0x400
        ".data", filepos 0x4d0, mempos 0x400, size 0x0
        ".bss", filepos 0x0, mempos 0x400, size 0x12c0
/usr/local/nachos/decstation-ultrix/bin/gcc -G 0 -c -I../userprog -I../threads -I../lib -I../userprog -I../threads -I../lib  -c -o sort.o sort.c
/usr/local/nachos/decstation-ultrix/bin/ld -T script -N start.o sort.o -o sort.coff
../bin/coff2noff sort.coff sort
numsections 3
Loading 3 sections:
        ".text", filepos 0xd0, mempos 0x0, size 0x300
        ".data", filepos 0x3d0, mempos 0x300, size 0x0
        ".bss", filepos 0x0, mempos 0x300, size 0x1000
/usr/local/nachos/decstation-ultrix/bin/gcc -G 0 -c -I../userprog -I../threads -I../lib -I../userprog -I../threads -I../lib  -c -o test1.o test1.c
/usr/local/nachos/decstation-ultrix/bin/ld -T script -N start.o test1.o -o test1.coff
../bin/coff2noff test1.coff test1
numsections 3
Loading 3 sections:
        ".text", filepos 0xd0, mempos 0x0, size 0x150
        ".data", filepos 0x220, mempos 0x150, size 0x0
        ".bss", filepos 0x0, mempos 0x150, size 0x0
/usr/local/nachos/decstation-ultrix/bin/gcc -G 0 -c -I../userprog -I../threads -I../lib -I../userprog -I../threads -I../lib  -c -o test2.o test2.c
/usr/local/nachos/decstation-ultrix/bin/ld -T script -N start.o test2.o -o test2.coff
../bin/coff2noff test2.coff test2
numsections 3
Loading 3 sections:
        ".text", filepos 0xd0, mempos 0x0, size 0x150
        ".data", filepos 0x220, mempos 0x150, size 0x0
        ".bss", filepos 0x0, mempos 0x150, size 0x0
make[1]: Leaving directory '/home/apoorv/nachos-4.0/code/test'
root@apoorv:/home/apoorv/nachos-4.0/code#
```

STEP 3: Installing emacs-

```
Screenshot
make: *** No rule to make target 'a'.  Stop.
root@apoorv:/home/apoorv/nachos-4.0/code/test#
root@apoorv:/home/apoorv/nachos-4.0/code/test# make all
make: Nothing to be done for 'all'.
root@apoorv:/home/apoorv/nachos-4.0/code/test# cd ..
root@apoorv:/home/apoorv/nachos-4.0/code# cd ..
root@apoorv:/home/apoorv/nachos-4.0# cd ..
root@apoorv:/home/apoorv# uname -a
Linux apoorv 4.15.0-29-generic #31~16.04.1-Ubuntu SMP Wed Jul 18 10:19:08 UTC 2018 i686 i686 i686 GNU/Linux
root@apoorv:/home/apoorv# g++ -dumpmachine
i686-linux-gnu
root@apoorv:/home/apoorv# gcc - dumpmachine
gcc: error: dumpmachine: No such file or directory
root@apoorv:/home/apoorv# gcc -dumpmachine
i686-linux-gnu
root@apoorv:/home/apoorv# cd nachos-4.0/code
root@apoorv:/home/apoorv/nachos-4.0/code# emacs Makefile.dep
The program 'emacs' can be found in the following packages:
 * emacs24
 * emacs24-nox
 * e3
 * emacs24-lucid
 * jove
Try: apt install <selected package>
root@apoorv:/home/apoorv/nachos-4.0/code# apt install emacs24
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following additional packages will be installed:
  emacs24-bin-common emacs24-common emacs24-common-non-dfsg emacs24-el libgif7 liblockfile-bin liblockfile1 libm17n-0 libotf0 m17n-db
Suggested packages:
  ncurses-term m17n-docs gawk
The following NEW packages will be installed:
  emacs24 emacs24-bin-common emacs24-common emacs24-common-non-dfsg emacs24-el libgif7 liblockfile-bin liblockfile1 libm17n-0 libotf0 m17n-db
0 upgraded, 11 newly installed, 0 to remove and 128 not upgraded.
Need to get 37.3 MB of archives.
After this operation, 107 MB of additional disk space will be used.
Do you want to continue? [Y/n] y
Get:1 http://in.archive.ubuntu.com/ubuntu xenial/main i386 liblockfile-bin i386 1.09-6ubuntu1 [10.7 kB]
Get:2 http://in.archive.ubuntu.com/ubuntu xenial/main i386 liblockfile1 i386 1.09-6ubuntu1 [7,926 B]
Get:3 http://in.archive.ubuntu.com/ubuntu xenial/main i386 emacs24-common-non-dfsg all 24.4+1-2 [4,545 kB]
Get:4 http://in.archive.ubuntu.com/ubuntu xenial-updates/main i386 emacs24-common all 24.5+1-6ubuntu1.1 [12.7 MB]
Get:5 http://in.archive.ubuntu.com/ubuntu xenial-updates/main i386 emacs24-bin-common i386 24.5+1-6ubuntu1.1 [103 kB]
Get:6 http://in.archive.ubuntu.com/ubuntu xenial-updates/main i386 libgif7 i386 5.1.4-0.3~16.04 [31.6 kB]
Get:7 http://in.archive.ubuntu.com/ubuntu xenial/main i386 libotf0 i386 0.9.13-3 [43.8 kB]
Get:8 http://in.archive.ubuntu.com/ubuntu xenial/main i386 m17n-db all 1.7.0-2 [1,239 kB]
Get:9 http://in.archive.ubuntu.com/ubuntu xenial/main i386 libm17n-0 i386 1.7.0-3 [253 kB]
Get:10 http://in.archive.ubuntu.com/ubuntu xenial-updates/main i386 emacs24 i386 24.5+1-6ubuntu1.1 [3,095 kB]
Get:11 http://in.archive.ubuntu.com/ubuntu xenial-updates/main i386 emacs24-el all 24.5+1-6ubuntu1.1 [15.3 MB]
Fetched 37.3 MB in 1min 48s (343 kB/s)
Selecting previously unselected package liblockfile-bin.
(Reading database ... 178097 files and directories currently installed.)
Preparing to unpack .../liblockfile-bin_1.09-6ubuntu1_i386.deb ...
Unpacking liblockfile-bin (1.09-6ubuntu1) ...
```

```
Screenshot
Selecting previously unselected package emacs24-common.
Preparing to unpack .../emacs24-common_24.5+1-6ubuntu1.1_all.deb ...
Unpacking emacs24-common (24.5+1-6ubuntu1.1) ...
Selecting previously unselected package emacs24-bin-common.
Preparing to unpack .../emacs24-bin-common_24.5+1-6ubuntu1.1_i386.deb ...
Unpacking emacs24-bin-common (24.5+1-6ubuntu1.1) ...
Selecting previously unselected package libgif7:i386.
Preparing to unpack .../libgif7_5.1.4-0.3~16.04_i386.deb ...
Unpacking libgif7:i386 (5.1.4-0.3~16.04) ...
Selecting previously unselected package libotf0:i386.
Preparing to unpack .../libotf0_0.9.13-3_i386.deb ...
Unpacking libotf0:i386 (0.9.13-3) ...
Selecting previously unselected package m17n-db.
Preparing to unpack .../m17n-db_1.7.0-2_all.deb ...
Unpacking m17n-db (1.7.0-2) ...
Selecting previously unselected package libm17n-0:i386.
Preparing to unpack .../libm17n-0_1.7.0-3_i386.deb ...
Unpacking libm17n-0:i386 (1.7.0-3) ...
Selecting previously unselected package emacs24.
Preparing to unpack .../emacs24_24.5+1-6ubuntu1.1_i386.deb ...
Unpacking emacs24 (24.5+1-6ubuntu1.1) ...
Selecting previously unselected package emacs24-el.
Preparing to unpack .../emacs24-el_24.5+1-6ubuntu1.1_all.deb ...
Unpacking emacs24-el (24.5+1-6ubuntu1.1) ...
Processing triggers for man-db (2.7.5-1) ...
Processing triggers for install-info (6.1.0.dfsg.1-5) ...
Processing triggers for hicolor-icon-theme (0.15-0ubuntu1.1) ...
Processing triggers for gnome-menus (3.13.3-6ubuntu3.1) ...
Processing triggers for desktop-file-utils (0.22-1ubuntu5.2) ...
Processing triggers for bamfdaemon (0.5.3~bzr0+16.04.20180209-0ubuntu1) ...
Rebuilding /usr/share/applications/bamf-2.index...
Processing triggers for mime-support (3.59ubuntu1) ...
Processing triggers for libc-bin (2.23-0ubuntu10) ...
Setting up liblockfile-bin (1.09-6ubuntu1) ...
Setting up liblockfile1:i386 (1.09-6ubuntu1) ...
Setting up emacs24-common-non-dfsg (24.4+1-2) ...
Setting up emacs24-common (24.5+1-6ubuntu1.1) ...
Setting up emacs24-bin-common (24.5+1-6ubuntu1.1) ...
update-alternatives: using /usr/bin/ctags.emacs24 to provide /usr/bin/ctags (ctags) in auto mode
update-alternatives: using /usr/bin/ebrowse.emacs24 to provide /usr/bin/ebrowse (ebrowse) in auto mode
update-alternatives: using /usr/bin/emacsclient.emacs24 to provide /usr/bin/emacsclient (emacsclient) in auto mode
update-alternatives: using /usr/bin/etags.emacs24 to provide /usr/bin/etags (etags) in auto mode
update-alternatives: using /usr/bin/grep-changelog.emacs24 to provide /usr/bin/grep-changelog (grep-changelog) in auto mode
Setting up libgif7:i386 (5.1.4-0.3~16.04) ...
Setting up libotf0:i386 (0.9.13-3) ...
Setting up m17n-db (1.7.0-2) ...
Setting up libm17n-0:i386 (1.7.0-3) ...
Setting up emacs24 (24.5+1-6ubuntu1.1) ...
update-alternatives: using /usr/bin/emacs24-x to provide /usr/bin/emacs (emacs) in auto mode
Install emacsen-common for emacs24
emacsen-common: Handling install of emacsen flavor emacs24
Wrote /etc/emacs24/site-start.d/00debian-vars.elc
Wrote /usr/share/emacs24/site-lisp/debian-startup.elc
Install dictionaries-common for emacs24
```

STEP 4: code/threads# ./nachos

```
Screenshot                                                                    9:29 PM
make[1]: Leaving directory '/home/apoorv/nachos-4.0/code/network'
cd network; make nachos
make[1]: Entering directory '/home/apoorv/nachos-4.0/code/network'
make[1]: 'nachos' is up to date.
make[1]: Leaving directory '/home/apoorv/nachos-4.0/code/network'
cd bin; make all
make[1]: Entering directory '/home/apoorv/nachos-4.0/code/bin'
make[1]: Nothing to be done for 'all'.
make[1]: Leaving directory '/home/apoorv/nachos-4.0/code/bin'
cd test; make all
make[1]: Entering directory '/home/apoorv/nachos-4.0/code/test'
make[1]: Nothing to be done for 'all'.
make[1]: Leaving directory '/home/apoorv/nachos-4.0/code/test'
root@apoorv:/home/apoorv/nachos-4.0/code# cd threads
root@apoorv:/home/apoorv/nachos-4.0/code/threads# ../nachos
bash: ../nachos: No such file or directory
root@apoorv:/home/apoorv/nachos-4.0/code/threads# ./nachos
*** thread 0 looped 0 times
*** thread 1 looped 0 times
*** thread 0 looped 1 times
*** thread 1 looped 1 times
*** thread 0 looped 2 times
*** thread 1 looped 2 times
*** thread 0 looped 3 times
*** thread 1 looped 3 times
*** thread 1 looped 4 times
*** thread 0 looped 4 times
No threads ready or runnable, and no pending interrupts.
Assuming the program completed.
Machine halting!

Ticks: total 2400, idle 110, system 2290, user 0
Disk I/O: reads 0, writes 0
Console I/O: reads 0, writes 0
Paging: faults 0
Network I/O: packets received 0, sent 0
root@apoorv:/home/apoorv/nachos-4.0/code/threads# ls
alarm.cc  alarm.o   debug.o    elevatortest.o  kernel.cc  kernel.o   main.cc  main.o    nachos       scheduler.h  stats.o   switch.o  swtch.s   synch.h      synchlist.h  sysdep.o   thread.h  timer.o
alarm.h   bitmap.o  elevator.o  interrupt.o     kernel.h   libtest.o  main.h   Makefile  scheduler.cc  scheduler.o  switch.h  switch.s  synch.cc  synchlist.cc  synch.o      thread.cc  thread.o
root@apoorv:/home/apoorv/nachos-4.0/code/threads# cd ..
root@apoorv:/home/apoorv/nachos-4.0/code# cd userprog
root@apoorv:/home/apoorv/nachos-4.0/code/userprog# ./nachos -x ../test/halt
Total threads number is 0
No threads ready or runnable, and no pending interrupts.
Assuming the program completed.
Machine halting!

Ticks: total 100, idle 90, system 10, user 0
Disk I/O: reads 0, writes 0
Console I/O: reads 0, writes 0
Paging: faults 0
Network I/O: packets received 0, sent 0
root@apoorv:/home/apoorv/nachos-4.0/code/userprog# cd ..
root@apoorv:/home/apoorv/nachos-4.0/code#
```

This nachos shows that nachos is installed on the system.

STEP 5: /code/userprog# ./nachos –x ../test/halt

```
Screenshot                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                
make[1]: Leaving directory '/home/apoorv/nachos-4.0/code/network'
cd network; make nachos
make[1]: Entering directory '/home/apoorv/nachos-4.0/code/network'
make[1]: 'nachos' is up to date.
make[1]: Leaving directory '/home/apoorv/nachos-4.0/code/network'
cd bin; make all
make[1]: Entering directory '/home/apoorv/nachos-4.0/code/bin'
make[1]: Nothing to be done for 'all'.
make[1]: Leaving directory '/home/apoorv/nachos-4.0/code/bin'
cd test; make all
make[1]: Entering directory '/home/apoorv/nachos-4.0/code/test'
make[1]: Nothing to be done for 'all'.
make[1]: Leaving directory '/home/apoorv/nachos-4.0/code/test'
root@apoorv:/home/apoorv/nachos-4.0/code# cd threads
root@apoorv:/home/apoorv/nachos-4.0/code/threads# ../nachos
bash: ../nachos: No such file or directory
root@apoorv:/home/apoorv/nachos-4.0/code/threads# ./nachos
*** thread 0 looped 0 times
*** thread 1 looped 0 times
*** thread 0 looped 1 times
*** thread 1 looped 1 times
*** thread 0 looped 2 times
*** thread 1 looped 2 times
*** thread 0 looped 3 times
*** thread 1 looped 3 times
*** thread 1 looped 4 times
*** thread 0 looped 4 times
No threads ready or runnable, and no pending interrupts.
Assuming the program completed.
Machine halting!

Ticks: total 2400, idle 110, system 2290, user 0
Disk I/O: reads 0, writes 0
Console I/O: reads 0, writes 0
Paging: faults 0
Network I/O: packets received 0, sent 0
root@apoorv:/home/apoorv/nachos-4.0/code/threads# ls
alarm.cc  alarm.o   debug.o     elevatortest.o  kernel.cc  kernel.o   main.cc  main.o    nachos        scheduler.h  stats.o   switch.o  swtch.s   synch.h      synchlist.h  sysdep.o   thread.h  timer.o
alarm.h   bitmap.o  elevator.o  interrupt.o     kernel.h   libtest.o  main.h   Makefile  scheduler.cc  scheduler.o  switch.h  switch.s  synch.cc  synchlist.cc  synch.o      thread.cc  thread.o
root@apoorv:/home/apoorv/nachos-4.0/code/threads# cd ..
root@apoorv:/home/apoorv/nachos-4.0/code# cd userprog
root@apoorv:/home/apoorv/nachos-4.0/code/userprog# ./nachos -x ../test/halt
Total threads number is 0
No threads ready or runnable, and no pending interrupts.
Assuming the program completed.
Machine halting!

Ticks: total 100, idle 90, system 10, user 0
Disk I/O: reads 0, writes 0
Console I/O: reads 0, writes 0
Paging: faults 0
Network I/O: packets received 0, sent 0
root@apoorv:/home/apoorv/nachos-4.0/code/userprog# cd ..
root@apoorv:/home/apoorv/nachos-4.0/code#
```

Now nachos is completely installed in the machine and the crossed compliler is already in **/usr/local**

CREATION OF A SYSCALL

System Call Procedure

SYSCALLS that are created by me:

- readint
- printint
- sub

STEPS FOR CREATION AND IMPLEMENTATION OF A SYSCALL

STEP 1: nachos-4.0/code/userprog/vi syscall.h

syscall.h Screenshot

```
#ifndef SYSCALLS_H
#define SYSCALLS_H

#include "copyright.h"

/* system call codes -- used by the stubs to tell the kernel which system call
 * is being asked for
 */
#define SC_Halt         0
#define SC_Exit         1
#define SC_Exec         2
#define SC_Join         3
#define SC_Create       4
#define SC_Open         5
#define SC_Read         6
#define SC_Write        7
#define SC_Close        8
#define SC_ThreadFork   9
#define SC_ThreadYield  10
#define SC_PrintInt     11
#define SC_ReadString   12
#define SC_PrintString  13
#define SC_Sub          14


#ifndef IN_ASM

/* The system call interface.  These are the operations the Nachos
 * kernel needs to support, to be able to run user programs.
 *
 * Each of these is invoked by a user program by simply calling the
 * procedure; an assembly language stub stuffs the system call code
 * into a register, and traps to the kernel.  The kernel procedures
 * are then invoked in the Nachos kernel, after appropriate error checking,
 * from the system call entry point in exception.cc.
 */

/* Stop Nachos, and print out performance stats */
void Halt();


/* Address space control operations: Exit, Exec, and Join */

/* This user program is done (status = 0 means exited normally). */
void Exit(int status);

/* A unique identifier for an executing user program (address space) */
typedef int SpaceId;

/* Run the executable, stored in the Nachos file "name", and return the
```

C/C++/ObjC Header Tab Width: 8 Ln 138, Col 1 INS

*syscall.h File Edit View Search Tools Documents Help

```
/* Create a Nachos file, with "name" */
void Create(char *name);

/* Open the Nachos file "name", and return an "OpenFileId" that can
 * be used to read and write to the file.
 */
OpenFileId Open(char *name);

/* Write "size" bytes from "buffer" to the open file. */
void Write(char *buffer, int size, OpenFileId id);

/* Read "size" bytes from the open file into "buffer".
 * Return the number of bytes actually read -- if the open file isn't
 * long enough, or if it is an I/O device, and there aren't enough
 * characters to read, return whatever is available (for I/O devices,
 * you should always wait until you can return at least one character).
 */
int Read(char *buffer, int size, OpenFileId id);

/* Close the file, we're done reading and writing to it. */
void Close(OpenFileId id);



/* User-level thread operations: Fork and Yield.  To allow multiple
 * threads to run within a user program.
 *
 * Could define other operations, such as LockAcquire, LockRelease, etc.
 */

/* Fork a thread to run a procedure ("func") in the *same* address space
 * as the current thread.
 */
void ThreadFork(void (*func)());

/* Yield the CPU to another runnable thread, whether in this address space
 * or not.
 */
void ThreadYield();

void PrintInt(int number);
void ReadString(char* buffer, int lengh);
void PrintString(char* string);
int Sub(int a, int b);

        //my System Call
#endif /* IN_ASM */

#endif /* SYSCALL_H */
```

C/C++/ObjC Header Tab Width: 8 Ln 137, Col 23 INS

STEP 2: nachos-4.0/code/userprog/exception.cc

exception.cc (~/nachos-4.0/code/userprog) - gedit

```cc
// exception.cc
//      Entry point into the Nachos kernel from user programs.
//      There are two kinds of things that can cause control to
//      transfer back to here from user code:
//
//      syscall -- The user code explicitly requests to call a procedure
//      in the Nachos kernel.  Right now, the only function we support is
//      "Halt".
//
//      exceptions -- The user code does something that the CPU can't handle.
//      For instance, accessing memory that doesn't exist, arithmetic errors,
//      etc.
//
//      Interrupts (which can also cause control to transfer from user
//      code into the Nachos kernel) are handled elsewhere.
//
// For now, this only handles the Halt() system call.
// Everything else core dumps.
//
// Copyright (c) 1992-1996 The Regents of the University of California.
// All rights reserved.  See copyright.h for copyright notice and limitation
// of liability and disclaimer of warranty provisions.

#include "copyright.h"
#include "main.h"
#include "syscall.h"
#include "system.h"

//----------------------------------------------------------------------
// ExceptionHandler
//      Entry point into the Nachos kernel.  Called when a user program
//      is executing, and either does a syscall, or generates an addressing
//      or arithmetic exception.
//
//      For system calls, the following is the calling convention:
//
//      system call code -- r2
//              arg1 -- r4
//              arg2 -- r5
//              arg3 -- r6
//              arg4 -- r7
//
//      The result of the system call, if any, must be put back into r2.
//
// And don't forget to increment the pc before returning. (Or else you'll
// loop making the same system call forever!
//
//      "which" is the kind of exception.  The list of possible exceptions
//      are in machine.h.
//----------------------------------------------------------------------
```

C++ Tab Width: 8 Ln 134, Col 33 INS

exception.cc (~/nachos-4.0/code/userprog) - gedit

```cc
                        DEBUG(dbgAddr, "Exec\n");
                        val = kernel->machine->ReadRegister(4);
                        kernel->StringCopy(tmpStr, retVal, 1024);
                        cout << "Exec: " << val << endl;
                        val = kernel->Exec(val);
                        kernel->machine->WriteRegister(2, val);
                        return;
*/              case SC_Exit:
                        DEBUG(dbgAddr, "Program exit\n");
                        val=kernel->machine->ReadRegister(4);
                        cout << "return value:" << val << endl;
                        kernel->currentThread->Finish();
                        break;
                case SC_ReadString:
                                {
                                        DEBUG('a', "ReadString() system call invoked \n");
                                        int maxLength = machine->ReadRegister(5);
                                        char* strConsole = new char[maxLength];
                                        if(strConsole == NULL)
                                        {
                                                DEBUG('a', "Not enough memory in system \n");
                                                machine->WriteRegister(2,-1);
                                                return;
                                        }
                                        int length = gSynchConsole->Read(strConsole,maxLength);
                                        if( length == -1)
                                                return;
                                        int vAdrr = machine->ReadRegister(4);
                                        int check = machine->System2User(vAdrr,length,strConsole);
                                        if(check == -1)
                                        {
                                                DEBUG('a', "Read String not conplete \n");
                                                machine->WriteRegister(2,-1);
                                        }
                                        break;
                                }

                        case SC_PrintString:
                                {
                                        DEBUG('a', "PrintString() system call invoked \n");
                                        int vAdrr = machine->ReadRegister(4);
                                        char* strConsole;
                                        strConsole = machine->User2System(vAdrr,3000);
                                        if (strConsole == NULL)
                                        {
                                                machine->WriteRegister(2,-1);
                                                return;
                                        }
                                        int i = 0;
                                        while (strConsole[i] != '\0')
```

C++ Tab Width: 8 Ln 83, Col 36 INS

Screenshot

Open ▾ Save

```
                        machine->WriteRegister(2,-1);
                        return;
                }
                int length = gSynchConsole->Read(strConsole,maxLength);
                if( length == -1)
                        return;
                int vAdrr = machine->ReadRegister(4);
                int check = machine->System2User(vAdrr,length,strConsole);
                if(check == -1)
                {
                        DEBUG('a', "Read String not complete \n");
                        machine->WriteRegister(2,-1);
                }
                break;
        }
case SC_PrintString:
        {
                DEBUG('a', "PrintString() system call inv
                int vAdrr = machine->ReadRegister(4);
                char* strConsole;
                strConsole = machine->User2System(vAdrr,3
                if (strConsole == NULL)
                {
                        machine->WriteRegister(2,-1);
                        return;
                }
                int i = 0;
                while (strConsole[i] != '\0')
                        i++;
                gSynchConsole->Write(strConsole,i);
                break;
        }
 case SC_Sub:
        int op1;
        op1 = machine->ReadRegister (4);
        int op2;
        op2 = machine->ReadRegister (5);
        int result;
        result = op1 - op2;
        printf ("\n %d\n", result);
        machine->WriteRegister (2, result);
        interrupt->Halt();
        break;

    default:
        cerr << "Unexpected system call " << type << "\n";
        break;
  }
  break;
default:
```

gnome-screenshot

Take Screenshot

- Grab the whole screen
- Grab the current window
- Select area to grab

Grab after a delay of 0 seconds

Effects

- Include pointer
- Include the window border

Apply effect: None

Take Screenshot

C++ ▾ Tab Width: 8 ▾ Ln 134, Col 39 ▾ INS

In step 1 and 2 we added the syscall prototype exception handling code

STEP 3: nachos-4.0/code/test/start.c (first create a new document and rename it to start.c)

start.c (~ Screenshot

```
        .end ThreadFork

        .globl ThreadYield
        .ent    ThreadYield
ThreadYield:
        addiu $2,$0,SC_ThreadYield
        syscall
        j       $31
        .end ThreadYield

        .globl  PrintInt
        .ent    PrintInt
PrintInt:
        addiu   $2,$0,SC_PrintInt
        syscall
        j       $31
        .end    PrintInt

        .globl ReadString
        .ent ReadString
ReadString:
        addiu $2,$0,SC_ReadString
        syscall
        j       $31
        .end ReadString

        .globl PrintString
        .ent PrintString
PrintString:
        addiu $2,$0,SC_PrintString
        syscall
        j       $31
        .end PrintString

        .globl Sub
        .ent Sub
Sub:
        addiu $2,$0,SC_Sub
        syscall
        j       $31
        .end Sub


/* dummy function to keep gcc happy */
        .globl  __main
        .ent    __main
__main:
        j       $31
        .end    __main
```

STEP 4: copy the same start.c code in start.s file and save it

STEP 5: nachos-4.0/code/test
emacs Makefile

Makefile (~/nachos-4.0/code/test) - gedit

Open ▾ Save

```
# use normal make for this Makefile
#
# Makefile for building user programs to run on top of Nachos
#
# Several things to be aware of:
#
#    Nachos assumes that the location of the program startup routine (the
#       location the kernel jumps to when the program initially starts up)
#       is at location 0.  This means: start.o must be the first .o passed
#       to ld, in order for the routine "Start" to be loaded at location 0
#

# if you are cross-compiling, you need to point to the right executables
# and change the flags to ld and the build procedure for as
GCCDIR = /usr/local/nachos/decstation-ultrix/bin/
LDFLAGS = -T script -N
ASFLAGS = -mips2
CPPFLAGS = $(INCDIR)


# if you aren't cross-compiling:
#GCCDIR =
#LDFLAGS = -N -T 0
#ASFLAGS =
#CPPFLAGS = -P $(INCDIR)


CC = $(GCCDIR)gcc
AS = $(GCCDIR)as
LD = $(GCCDIR)ld

CPP = /lib/cpp
INCDIR =-I../userprog -I../threads -I../lib
CFLAGS = -G 0 -c $(INCDIR)

all: halt shell matmult sort test1 test2 readstring printstring sub

start.o: start.s ../userprog/syscall.h
	$(CPP) $(CPPFLAGS) start.s > strt.s
	$(AS) $(ASFLAGS) -o start.o strt.s
	rm strt.s

#halt.o: halt.c
#	$(CC) $(CFLAGS) -c halt.c
halt: halt.o start.o
	$(LD) $(LDFLAGS) start.o halt.o -o halt.coff
	../bin/coff2noff halt.coff halt

#shell.o: shell.c
#	$(CC) $(CFLAGS) -c shell.c
```

Makefile ▾ Tab Width: 8 ▾ Ln 36, Col 68 ▾ INS

Makefile (~/nachos-4.0/code/test) - gedit

```
#halt.o: halt.c
#       $(CC) $(CFLAGS) -c halt.c
halt: halt.o start.o
        $(LD) $(LDFLAGS) start.o halt.o -o halt.coff
        ../bin/coff2noff halt.coff halt

#shell.o: shell.c
#       $(CC) $(CFLAGS) -c shell.c
shell: shell.o start.o
        $(LD) $(LDFLAGS) start.o shell.o -o shell.coff
        ../bin/coff2noff shell.coff shell

#sort.o: sort.c
#       $(CC) $(CFLAGS) -c sort.c
sort: sort.o start.o
        $(LD) $(LDFLAGS) start.o sort.o -o sort.coff
        ../bin/coff2noff sort.coff sort

#matmult.o: matmult.c
#       $(CC) $(CFLAGS) -c matmult.c
matmult: matmult.o start.o
        $(LD) $(LDFLAGS) start.o matmult.o -o matmult.coff
        ../bin/coff2noff matmult.coff matmult

test1: test1.o start.o
        $(LD) $(LDFLAGS) start.o test1.o -o test1.coff
        ../bin/coff2noff test1.coff test1

test2: test2.o start.o
        $(LD) $(LDFLAGS) start.o test2.o -o test2.coff
        ../bin/coff2noff test2.coff test2

readstring.o: readstring.c
        $(CC) $(CFLAGS) -c readstring.c
readstring: readstring.o start.o
        $(LD) $(LDFLAGS) start.o readstring.o -o readstring.coff
        ../bin/coff2noff readstring.coff readstring

printstring.o: printstring.c
        $(CC) $(CFLAGS) -c printstring.c
printstring: printstring.o start.o
        $(LD) $(LDFLAGS) start.o printstring.o -o printstring.coff
        ../bin/coff2noff printstring.coff printstring



sub.o: sub.c
        $(CC) $(CFLAGS) -c sub.c
sub: sub.o start.o
        $(LD) $(LDFLAGS) start.o sub.o -o sub.coff
        ../bin/coff2noff sub.coff sub
```

Makefile is edited using emacs editor

STEP 6: create a c file in test folder.

* printstring.c
* readstring.c
* sub.c

printstring.c

printstring.c (~/nachos-4.0/code/test) - gedit

Open

reads

```c
#include "syscall.h"

int main()
{
        char buffer[255];
        ReadString(buffer,254);
        PrintString(buffer);
        return 0;
}
```

readstring.c

Open

readstring.c

```c
#include "syscall.h"

int main()
{
        char* string[50];
        ReadString(string, 50);
        return 0;
}
```

sub.c

```c
#include "syscall.h"

int main()
{
        int result;
        result = Sub(43, 23);
        Halt();
}
```

Now all the codes for syscalls and tests are done. We need to compile them using make command.

STEP 7: nachos-4.0/code/make all

```
inal Terminal File Edit View Search Terminal Help
root@apoorv: /home/apoorv/nachos-4.0/code
make[1]: Leaving directory '/home/apoorv/nachos-4.0/code/userprog'
Makefile:9: recipe for target 'all' failed
make: *** [all] Error 2
root@apoorv:/home/apoorv/nachos-4.0/code# make all
cd threads; make depend
make[1]: Entering directory '/home/apoorv/nachos-4.0/code/threads'
g++ -Wno-deprecated -I../lib -I../threads -I../machine -DTHREADS -Dx86 -DLINUX -DBSD -
M ../lib/bitmap.cc ../lib/debug.cc ../lib/hash.cc ../lib/libtest.cc ../lib/list.cc ../
lib/sysdep.cc ../machine/interrupt.cc ../machine/stats.cc ../machine/timer.cc ../threa
ds/alarm.cc ../threads/kernel.cc ../threads/main.cc ../threads/scheduler.cc ../threads
/synch.cc ../threads/synchlist.cc ../threads/thread.cc ../machine/elevatortest.cc ../m
achine/elevator.cc > makedep
echo '/^# DO NOT DELETE THIS LINE/+2,$d' >eddep
echo '$r makedep' >>eddep
echo 'w' >>eddep
echo 'q' >>eddep
ed - Makefile < eddep
rm eddep makedep
echo '# DEPENDENCIES MUST END AT END OF FILE' >> Makefile
echo '# IF YOU PUT STUFF HERE IT WILL GO AWAY' >> Makefile
echo '# see make depend above' >> Makefile
make[1]: Leaving directory '/home/apoorv/nachos-4.0/code/threads'
cd threads; make nachos
make[1]: Entering directory '/home/apoorv/nachos-4.0/code/threads'
make[1]: 'nachos' is up to date.
make[1]: Leaving directory '/home/apoorv/nachos-4.0/code/threads'
cd userprog; make depend
make[1]: Entering directory '/home/apoorv/nachos-4.0/code/userprog'
g++ -Wno-deprecated -I../bin -I../filesys -I../userprog -I../threads -I../machine -I..
/lib -DTHREADS -DUSER_PROGRAM -DFILESYS_NEEDED -DFILESYS_STUB -Dx86 -DLINUX -DBSD -M .
./lib/bitmap.cc ../lib/debug.cc ../lib/hash.cc ../lib/libtest.cc ../lib/list.cc ../lib
/sysdep.cc ../machine/interrupt.cc ../machine/stats.cc ../machine/timer.cc ../threads/
alarm.cc ../threads/kernel.cc ../threads/main.cc ../threads/scheduler.cc ../threads/sy
nch.cc ../threads/synchlist.cc ../threads/thread.cc ../machine/elevatortest.cc ../mach
ine/elevator.cc ../userprog/addrspace.cc ../userprog/exception.cc ../userprog/synchcon
sole.cc ../userprog/userkernel.cc ../machine/console.cc ../machine/machine.cc ../machi
ne/mipssim.cc ../machine/translate.cc ../filesys/synchdisk.cc ../machine/disk.cc > mak
edep
echo '/^# DO NOT DELETE THIS LINE/+2,$d' >eddep
echo '$r makedep' >>eddep
```

```
root@apoorv: /home/apoorv/nachos-4.0/code
make[1]: Entering directory '/home/apoorv/nachos-4.0/code/test'
/lib/cpp -I../userprog -I../threads -I../lib start.s > strt.s
/usr/local/nachos/decstation-ultrix/bin/as -mips2 -o start.o strt.s
rm strt.s
/usr/local/nachos/decstation-ultrix/bin/ld -T script -N start.o halt.o -o halt.coff
../bin/coff2noff halt.coff halt
numsections 3
Loading 3 sections:
        ".text", filepos 0xd0, mempos 0x0, size 0x140
        ".data", filepos 0x210, mempos 0x140, size 0x0
        ".bss", filepos 0x0, mempos 0x140, size 0x0
/usr/local/nachos/decstation-ultrix/bin/ld -T script -N start.o shell.o -o shell.coff
../bin/coff2noff shell.coff shell
numsections 3
Loading 3 sections:
        ".text", filepos 0xd0, mempos 0x0, size 0x240
        ".data", filepos 0x310, mempos 0x240, size 0x0
        ".bss", filepos 0x0, mempos 0x240, size 0x0
/usr/local/nachos/decstation-ultrix/bin/ld -T script -N start.o matmult.o -o matmult.c
off
../bin/coff2noff matmult.coff matmult
numsections 3
Loading 3 sections:
        ".text", filepos 0xd0, mempos 0x0, size 0x430
        ".data", filepos 0x500, mempos 0x430, size 0x0
        ".bss", filepos 0x0, mempos 0x430, size 0x12c0
/usr/local/nachos/decstation-ultrix/bin/ld -T script -N start.o sort.o -o sort.coff
../bin/coff2noff sort.coff sort
numsections 3
Loading 3 sections:
        ".text", filepos 0xd0, mempos 0x0, size 0x330
        ".data", filepos 0x400, mempos 0x330, size 0x0
```

```
        ".bss", filepos 0x0, mempos 0x150, size 0x0
/usr/local/nachos/decstation-ultrix/bin/gcc -G 0 -c -I../userprog -I../threads -I../lib -c printstring.c
/usr/local/nachos/decstation-ultrix/bin/ld -T script -N start.o printstring.o -o printstring.coff
../bin/coff2noff printstring.coff printstring
numsections 3
Loading 3 sections:
        ".text", filepos 0xd0, mempos 0x0, size 0x160
        ".data", filepos 0x230, mempos 0x160, size 0x0
        ".bss", filepos 0x0, mempos 0x160, size 0x0
/usr/local/nachos/decstation-ultrix/bin/gcc -G 0 -c -I../userprog -I../threads -I../lib -c sub.c
/usr/local/nachos/decstation-ultrix/bin/ld -T script -N start.o sub.o -o sub.coff
../bin/coff2noff sub.coff sub
numsections 3
Loading 3 sections:
        ".text", filepos 0xd0, mempos 0x0, size 0x150
        ".data", filepos 0x220, mempos 0x150, size 0x0
        ".bss", filepos 0x0, mempos 0x150, size 0x0
make[1]: Leaving directory '/home/apoorv/nachos-4.0/code/test'
root@apoorv:/home/apoorv/nachos-4.0/code# ls test
halt      halt.o     matmult      matmult.o     printstring.coff  readstring.c     script    shell.coff  sort.c     start.c  sub      sub.o    test1.coff  test2.c
halt.c    Makefile   matmult.c    printstring   printstring.o     readstring.coff  shell     shell.o     sort.coff  start.o  sub.c    test1    test1.o     test2.coff
halt.coff Makefile~  matmult.coff  printstring.c readstring       readstring.o     shell.c   sort        sort.o     start.s  sub.coff test1.c  test2       test2.o
root@apoorv:/home/apoorv/nachos-4.0/code# make
cd threads; make depend
make[1]: Entering directory '/home/apoorv/nachos-4.0/code/threads'
g++ -Wno-deprecated -I../lib -I../threads -I../machine -DTHREADS -Dx86 -DLINUX -DBSD -M ../lib/bitmap.cc ../lib/debug.cc ../lib/hash.cc ../lib/libtest.cc ../lib/list.cc ../lib/sysdep.cc ../machine/interru
pt.cc ../machine/stats.cc ../machine/timer.cc ../threads/alarm.cc ../threads/kernel.cc ../threads/main.cc ../threads/scheduler.cc ../threads/synch.cc ../threads/synchlist.cc ../threads/thread.cc ../machin
e/elevatortest.cc ../machine/elevator.cc > makedep
echo '/^# DO NOT DELETE THIS LINE/+2,$d' >eddep
echo '$r makedep' >>eddep
echo 'w' >>eddep
echo 'q' >>eddep
ed - Makefile < eddep
rm eddep makedep
echo '# DEPENDENCIES MUST END AT END OF FILE' >> Makefile
echo '# IF YOU PUT STUFF HERE IT WILL GO AWAY' >> Makefile
echo '# see make depend above' >> Makefile
make[1]: Leaving directory '/home/apoorv/nachos-4.0/code/threads'
cd threads; make nachos
make[1]: Entering directory '/home/apoorv/nachos-4.0/code/threads'
make[1]: 'nachos' is up to date.
make[1]: Leaving directory '/home/apoorv/nachos-4.0/code/threads'
cd userprog; make depend
make[1]: Entering directory '/home/apoorv/nachos-4.0/code/userprog'
g++ -Wno-deprecated -I../bin -I../filesys -I../userprog -I../threads -I../machine -I../lib -DTHREADS -DUSER_PROGRAM -DFILESYS_NEEDED -DFILESYS_STUB -Dx86 -DLINUX -DBSD -M ../lib/bitmap.cc ../lib/debug.cc
../lib/hash.cc ../lib/libtest.cc ../lib/list.cc ../lib/sysdep.cc ../machine/interrupt.cc ../machine/stats.cc ../machine/timer.cc ../threads/alarm.cc ../threads/kernel.cc ../threads/main.cc ../threads/sche
duler.cc ../threads/synch.cc ../threads/synchlist.cc ../threads/thread.cc ../machine/elevatortest.cc ../machine/elevator.cc ../userprog/addrspace.cc ../userprog/exception.cc ../userprog/synchconsole.cc ..
/userprog/userkernel.cc ../machine/console.cc ../machine/machine.cc ../machine/mipssim.cc ../machine/translate.cc ../filesys/synchdisk.cc ../machine/disk.cc > makedep
echo '/^# DO NOT DELETE THIS LINE/+2,$d' >eddep
echo '$r makedep' >>eddep
echo 'w' >>eddep
echo 'q' >>eddep
ed - Makefile < eddep
rm eddep makedep
```

In the test folder, binary and .coff files are created which shows that syscalls and tests were compiled successfully. Now we will implement them

STEP 8: nachos-4.0/code# ./userprog/nachos –rs 1023 –x./test/sub

```
cd test; make all
make[1]: Entering directory '/home/apoorv/nachos-4.0/code/test'
make[1]: Nothing to be done for 'all'.
make[1]: Leaving directory '/home/apoorv/nachos-4.0/code/test'
root@apoorv:/home/apoorv/nachos-4.0/code# ./userprog/nachos-rs 1023 -x ./test/sub
bash: ./userprog/nachos-rs: No such file or directory
root@apoorv:/home/apoorv/nachos-4.0/code# ./userprog/nachos -rs 1023 -x ./test/sub
Total threads number is 0
No threads ready or runnable, and no pending interrupts.
Assuming the program completed.
Machine halting!

Ticks: total 25, idle 5, system 20, user 0
Disk I/O: reads 0, writes 0
Console I/O: reads 0, writes 0
Paging: faults 0
Network I/O: packets received 0, sent 0
root@apoorv:/home/apoorv/nachos-4.0/code# ./userprog/nachos -rs 1023 -x ./test/readstring
Total threads number is 0
No threads ready or runnable, and no pending interrupts.
Assuming the program completed.
Machine halting!

Ticks: total 25, idle 5, system 20, user 0
Disk I/O: reads 0, writes 0
Console I/O: reads 0, writes 0
Paging: faults 0
Network I/O: packets received 0, sent 0
root@apoorv:/home/apoorv/nachos-4.0/code# ./userprog/nachos -rs 1023 -x ./test/readstring
Total threads number is 0
No threads ready or runnable, and no pending interrupts.
Assuming the program completed.
Machine halting!

Ticks: total 25, idle 5, system 20, user 0
Disk I/O: reads 0, writes 0
Console I/O: reads 0, writes 0
Paging: faults 0
Network I/O: packets received 0, sent 0
root@apoorv:/home/apoorv/nachos-4.0/code# cd threads
root@apoorv:/home/apoorv/nachos-4.0/code/threads# ls
alarm.cc  alarm.o   debug.o     elevatortest.o  kernel.cc  kernel.o   main.cc  main.o    nachos       scheduler.h  stats.o   switch.o  swtch.s   synch.h      synchlist.h  sysdep.o   thread.h  timer.o
alarm.h   bitmap.o  elevator.o  interrupt.o     kernel.h   libtest.o  main.h   Makefile  scheduler.cc  scheduler.o  switch.h  switch.s  synch.cc  synchlist.cc  synch.o      thread.cc  thread.o
root@apoorv:/home/apoorv/nachos-4.0/code/threads# ./userprog/nachos -rs 1023 -x ./test/readstring.c
bash: ./userprog/nachos: No such file or directory
root@apoorv:/home/apoorv/nachos-4.0/code/threads# ./userprog/nachos -rs 1023 -x ./test/readstring
bash: ./userprog/nachos: No such file or directory
root@apoorv:/home/apoorv/nachos-4.0/code/threads# cd ..
root@apoorv:/home/apoorv/nachos-4.0/code# ./userprog/nachos -rs 1023 -x ./test/readstring
Total threads number is 0
No threads ready or runnable, and no pending interrupts.
Assuming the program completed.
Machine halting!
```

Similarly, we implement the other two syscalls.

```
cd test; make all
make[1]: Entering directory '/home/apoorv/nachos-4.0/code/test'
make[1]: Nothing to be done for 'all'.
make[1]: Leaving directory '/home/apoorv/nachos-4.0/code/test'
root@apoorv:/home/apoorv/nachos-4.0/code# ./userprog/nachos-rs 1023 -x ./test/sub
bash: ./userprog/nachos-rs: No such file or directory
root@apoorv:/home/apoorv/nachos-4.0/code# ./userprog/nachos -rs 1023 -x ./test/sub
Total threads number is 0
No threads ready or runnable, and no pending interrupts.
Assuming the program completed.
Machine halting!

Ticks: total 25, idle 5, system 20, user 0
Disk I/O: reads 0, writes 0
Console I/O: reads 0, writes 0
Paging: faults 0
Network I/O: packets received 0, sent 0
root@apoorv:/home/apoorv/nachos-4.0/code# ./userprog/nachos -rs 1023 -x ./test/readstring
Total threads number is 0
No threads ready or runnable, and no pending interrupts.
Assuming the program completed.
Machine halting!

Ticks: total 25, idle 5, system 20, user 0
Disk I/O: reads 0, writes 0
Console I/O: reads 0, writes 0
Paging: faults 0
Network I/O: packets received 0, sent 0
root@apoorv:/home/apoorv/nachos-4.0/code# ./userprog/nachos -rs 1023 -x ./test/readstring
Total threads number is 0
No threads ready or runnable, and no pending interrupts.
Assuming the program completed.
Machine halting!

Ticks: total 25, idle 5, system 20, user 0
Disk I/O: reads 0, writes 0
Console I/O: reads 0, writes 0
Paging: faults 0
Network I/O: packets received 0, sent 0
root@apoorv:/home/apoorv/nachos-4.0/code# cd threads
root@apoorv:/home/apoorv/nachos-4.0/code/threads# ls
alarm.cc  alarm.o   debug.o    elevatortest.o  kernel.cc  kernel.o   main.cc  main.o    nachos       scheduler.h  stats.o   switch.o  swtch.s   synch.h      synchlist.h  sysdep.o   thread.h  timer.o
alarm.h   bitmap.o  elevator.o  interrupt.o     kernel.h   libtest.o  main.h   Makefile  scheduler.cc  scheduler.o  switch.h  switch.s  synch.cc  synchlist.cc  synch.o      thread.cc  thread.o
root@apoorv:/home/apoorv/nachos-4.0/code/threads# ./userprog/nachos -rs 1023 -x ./test/readstring.c
bash: ./userprog/nachos: No such file or directory
root@apoorv:/home/apoorv/nachos-4.0/code/threads# ./userprog/nachos -rs 1023 -x ./test/readstring
bash: ./userprog/nachos: No such file or directory
root@apoorv:/home/apoorv/nachos-4.0/code/threads# cd ..
root@apoorv:/home/apoorv/nachos-4.0/code# ./userprog/nachos -rs 1023 -x ./test/readstring
Total threads number is 0
No threads ready or runnable, and no pending interrupts.
Assuming the program completed.
Machine halting!
```

This is how syscalls are created and implemented in NACHOS using MIPS CROSS COMPILER

Issues faced while installing and creating syscalls

- Most of the issues faced by us during the installation of nachos was because of makefile.
- Firstly nachos/code/makefile. We had to change the bin path.
- Next makefile.dep. This is different for different compilers and we had to find the code for the compiller we used in this project and type in this file.

```
# CPU = x86, OS = linux
HOST = -Dx86 -DLINUX -DBSD
DISASM = disasm
```

- Now we move to the makefiles in code/test.
- Nachos/code/test/makefile. This file contains the gcc directory for mips compiler. Earlier our mips compiler was in the home directory. After several failed tries we understood that it has to be moves in /usr/local. After moving it to that directory this issue was resolved.

```
apoorv: /home/apoorv/nachos-4.0/code
To run a command as administrator (user "root"), use "sudo <command>".
See "man sudo_root" for details.

apoorv@apoorv:~$ sudo su
[sudo] password for apoorv:
root@apoorv:/home/apoorv# ls
Desktop    Downloads         Music   Pictures  Templates
Documents  examples.desktop  nachos  Public    Videos
root@apoorv:/home/apoorv# mv nachos ../usr/local
mv: cannot move 'nachos' to '../usr/local': No such file or directory
root@apoorv:/home/apoorv# mv nachos ./usr/local
mv: cannot move 'nachos' to './usr/local': No such file or directory
root@apoorv:/home/apoorv# mv nachos ./usr/local/
mv: cannot move 'nachos' to './usr/local/': No such file or directory
root@apoorv:/home/apoorv# sudo mv nachos /usr/local
root@apoorv:/home/apoorv# ls
Desktop  Documents  Downloads  examples.desktop  Music  nachos-4.0  nachos-4.0.tar.gz  Pictures  Public  Templates  Vi
root@apoorv:/home/apoorv# cd nachos-4.0/code
root@apoorv:/home/apoorv/nachos-4.0/code# make
cd threads; make depend
```

Make command did not work at first attempt

```
rm eddep makedep
echo '# DEPENDENCIES MUST END AT END OF FILE' >> Makefile
echo '# IF YOU PUT STUFF HERE IT WILL GO AWAY' >> Makefile
echo '# see make depend above' >> Makefile
make[1]: Leaving directory '/home/apoorv/nachos-4.0/code/threads'
cd threads; make nachos
make[1]: Entering directory '/home/apoorv/nachos-4.0/code/threads'
make[1]: 'nachos' is up to date.
make[1]: Leaving directory '/home/apoorv/nachos-4.0/code/threads'
cd userprog; make depend
make[1]: Entering directory '/home/apoorv/nachos-4.0/code/userprog'
g++ -Wno-deprecated -I../bin -I../filesys -I../userprog -I../threads -I../machine -I../lib -DTHREADS -DUSER_PROGRAM -DFILESYS_NEEDED -DFILESYS_STUB -Dx86 -DLINUX -DBSD -M ../lib/bitmap.cc ../lib/debug.cc
../lib/hash.cc ../lib/libtest.cc ../lib/list.cc ../lib/sysdep.cc ../machine/interrupt.cc ../machine/stats.cc ../machine/timer.cc ../threads/alarm.cc ../threads/kernel.cc ../threads/main.cc ../threads/sche
duler.cc ../threads/synch.cc ../threads/synchlist.cc ../threads/thread.cc ../machine/elevatortest.cc ../machine/elevator.cc ../userprog/addrspace.cc ../userprog/exception.cc ../userprog/synchconsole.cc ..
/userprog/userkernel.cc ../machine/console.cc ../machine/machine.cc ../machine/mipssim.cc ../machine/translate.cc ../filesys/synchdisk.cc ../machine/disk.cc > makedep
echo '/^# DO NOT DELETE THIS LINE/+2,$d' >eddep
echo '$r makedep' >>eddep
echo 'w' >>eddep
echo 'q' >>eddep
ed - Makefile < eddep
rm eddep makedep
echo '# DEPENDENCIES MUST END AT END OF FILE' >> Makefile
echo '# IF YOU PUT STUFF HERE IT WILL GO AWAY' >> Makefile
echo '# see make depend above' >> Makefile
make[1]: Leaving directory '/home/apoorv/nachos-4.0/code/userprog'
cd userprog; make nachos
make[1]: Entering directory '/home/apoorv/nachos-4.0/code/userprog'
g++ -Wno-deprecated -g -Wall -I../bin -I../filesys -I../userprog -I../threads -I../machine -I../lib -DTHREADS -DUSER_PROGRAM -DFILESYS_NEEDED -DFILESYS_STUB -Dx86 -DLINUX -DBSD -DCHANGED -c ../userprog/ex
ception.cc
../userprog/exception.cc: In function 'void ExceptionHandler(ExceptionType)':
../userprog/exception.cc:85:22: error: 'machine' was not declared in this scope
     int maxLength = machine->ReadRegister(5);
                     ^
../userprog/exception.cc:93:19: error: 'gSynchConsole' was not declared in this scope
     int length = gSynchConsole->Read(strConsole,maxLength);
                  ^
../userprog/exception.cc:109:18: error: 'machine' was not declared in this scope
     int vAdrr = machine->ReadRegister(4);
                 ^
../userprog/exception.cc:120:6: error: 'gSynchConsole' was not declared in this scope
     gSynchConsole->Write(strConsole,l);
     ^
../userprog/exception.cc:125:11: error: 'machine' was not declared in this scope
    op1 = machine->ReadRegister (4);
          ^
../userprog/exception.cc:132:5: error: 'interrupt' was not declared in this scope
    interrupt->Halt();
    ^
../Makefile.common:145: recipe for target 'exception.o' failed
make[1]: *** [exception.o] Error 1
make[1]: Leaving directory '/home/apoorv/nachos-4.0/code/userprog'
Makefile:9: recipe for target 'all' failed
make: *** [all] Error 2
root@apoorv:/home/apoorv/nachos-4.0/code#
```

```
apoorvsingh@apoorvsingh-Nitro-NP515-51:~$ ls
Desktop     examples.desktop          NACHOS      nachos-4.0.tar  Templates
Documents   mips-x86_64.linux-xgcc.tar.gz  nachos-3.4  Pictures        Videos
Downloads   Music                     nachos-4.0  Public
apoorvsingh@apoorvsingh-Nitro-NP515-51:~$ tar -xf nachos-java.tar.gz
apoorvsingh@apoorvsingh-Nitro-NP515-51:~$ ls
Desktop                     Music           nachos-java.tar.gz
Documents                   nachos          Pictures
Downloads                   NACHOS          Public
examples.desktop            nachos-3.4      Templates
mips-x86_64.linux-xgcc.tar.gz  nachos-4.0      Videos
mips-x86.linux-xgcc.tar.gz  nachos-4.0.tar
apoorvsingh@apoorvsingh-Nitro-NP515-51:~$ chmod 777 $HOME/nachos/bin/nachos
apoorvsingh@apoorvsingh-Nitro-NP515-51:~$ tar -xf mips.x86.linux.xgcc.tar.gz
tar: mips.x86.linux.xgcc.tar.gz: Cannot open: No such file or directory
tar: Error is not recoverable: exiting now
apoorvsingh@apoorvsingh-Nitro-NP515-51:~$ tar -xf mips-x86.linux-xgcc.tar.gz
apoorvsingh@apoorvsingh-Nitro-NP515-51:~$ ls
Desktop                     mips-x86.linux-xgcc.tar.gz  nachos-4.0.tar
Documents                   Music                       nachos-java.tar.gz
Downloads                   nachos                      Pictures
examples.desktop            NACHOS                      Public
mips-x86_64.linux-xgcc.tar.gz  nachos-3.4                  Templates
mips-x86.linux-xgcc         nachos-4.0                  Videos
apoorvsingh@apoorvsingh-Nitro-NP515-51:~$ emacs .profile
apoorvsingh@apoorvsingh-Nitro-NP515-51:~$ emacs .profile
apoorvsingh@apoorvsingh-Nitro-NP515-51:~$ ls
Desktop                     mips-x86.linux-xgcc.tar.gz  nachos-4.0.tar
Documents                   Music                       nachos-java.tar.gz
Downloads                   nachos                      Pictures
examples.desktop            NACHOS                      Public
mips-x86_64.linux-xgcc.tar.gz  nachos-3.4                  Templates
mips-x86.linux-xgcc         nachos-4.0                  Videos
apoorvsingh@apoorvsingh-Nitro-NP515-51:~$ cd nachos
apoorvsingh@apoorvsingh-Nitro-NP515-51:~/nachos$ ls
ag   machine   network  proj2  proj4   security  threads   vm
bin  Makefile  proj1    proj3  README  test      userprog
apoorvsingh@apoorvsingh-Nitro-NP515-51:~/nachos$ cd proj1
apoorvsingh@apoorvsingh-Nitro-NP515-51:~/nachos/proj1$ ls
Makefile  nachos.conf
apoorvsingh@apoorvsingh-Nitro-NP515-51:~/nachos/proj1$ make
javac -classpath . -d . -sourcepath ../.. -g ../threads/ThreadedKernel.java
make: javac: Command not found
../Makefile:42: recipe for target 'nachos/threads/ThreadedKernel.class' failed
make: *** [nachos/threads/ThreadedKernel.class] Error 127
apoorvsingh@apoorvsingh-Nitro-NP515-51:~/nachos/proj1$
```

INFERENCE FROM THE PROJECT

- Through this project we got know the actual working of an operating system, how a bootloader boots the first instance of an operating system. Through the kernel files we observed how actually the system calls are written in C and assembly language. With several failed tries and eventually after much hard- work and effort we learned and successfully able to change the kernel files and observe the changes in the operating system. We researched on the system calls and added and modified them in the kernel of the NACHOS and modified the kernel. Through this we learned how can the kernel of a system can be modified.
- The next work we did was on developing the NACHOS application. For understanding and writing the code we studied the beginner's assembly language and interpreted and write a code by taking reference from an available example.

REFERENCES

- "Guide to Nachos, University of Pittsburgh".
- "Compiling C and C++ Programs, University of Wisconsin".
- "Nachos Beginner's Guide, Level 2: System calls and exceptions, Linköping University".
- "Machine Class at Nachos Documentation, University of California, Berkeley".
- "A road map through NachOS, Duke University".